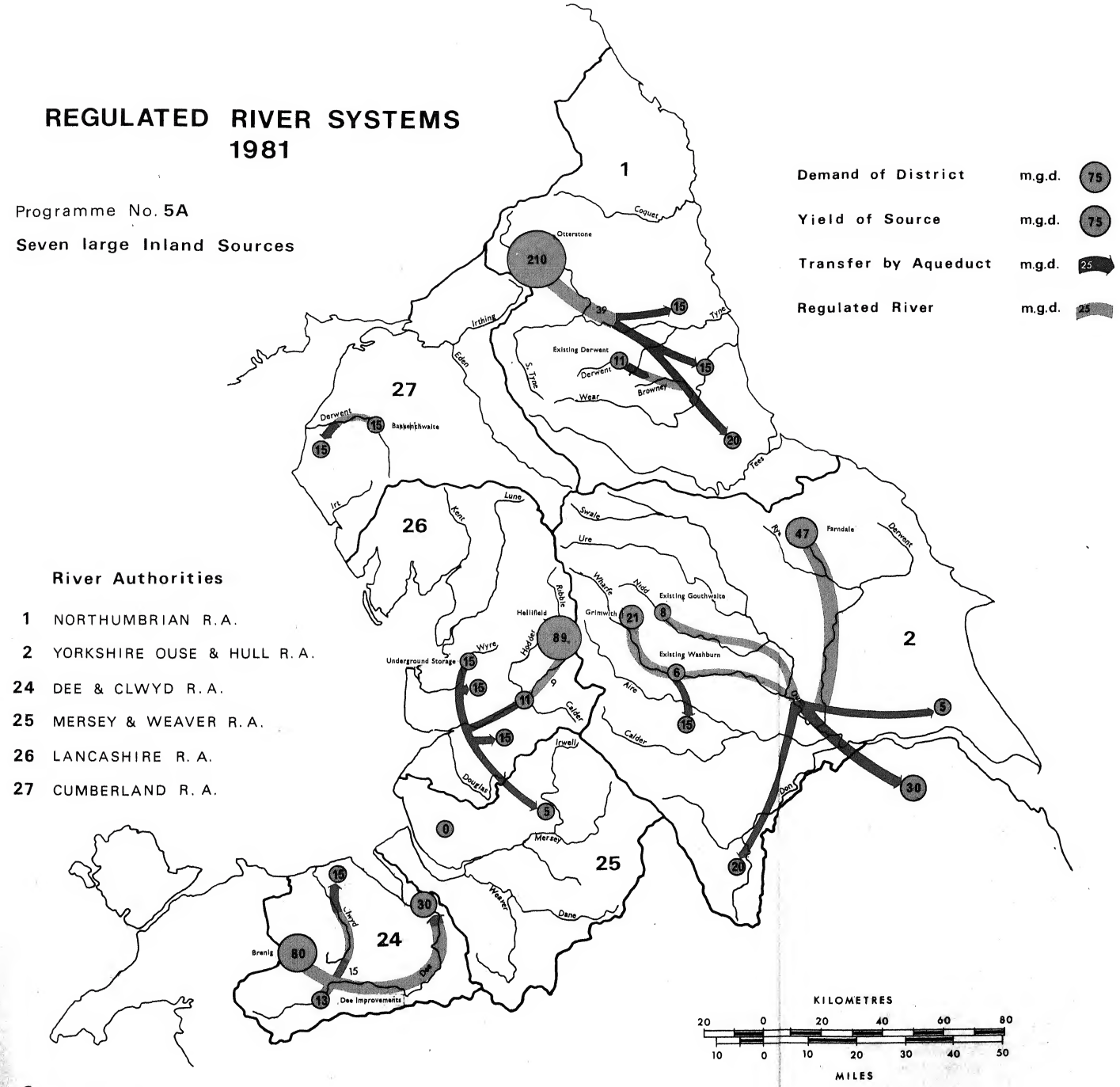
REGULATED RIVER SYSTEMS 1981

Programme No. 5A

Seven large Inland Sources



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REGULATED RIVER SYSTEMS 1992

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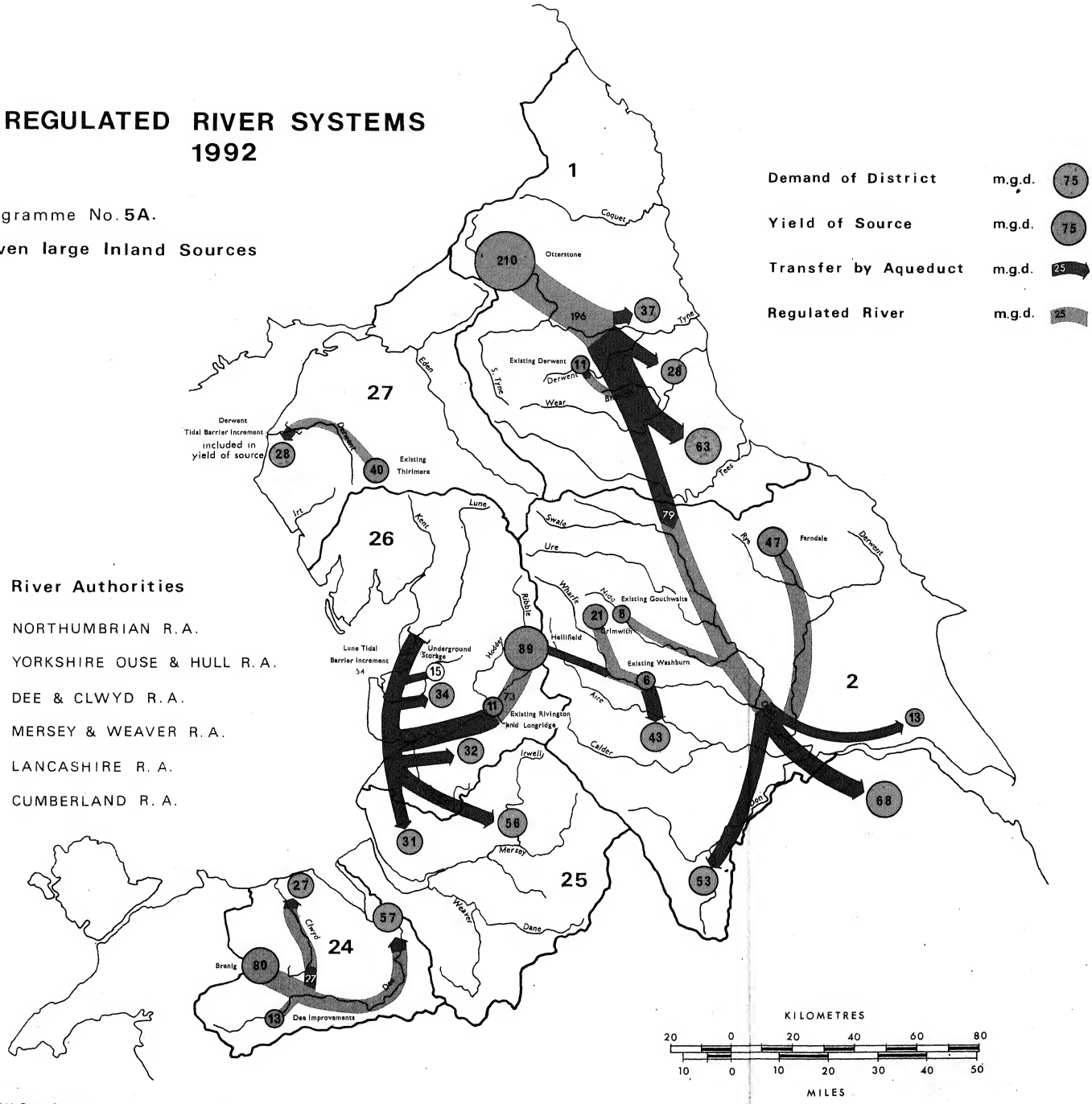

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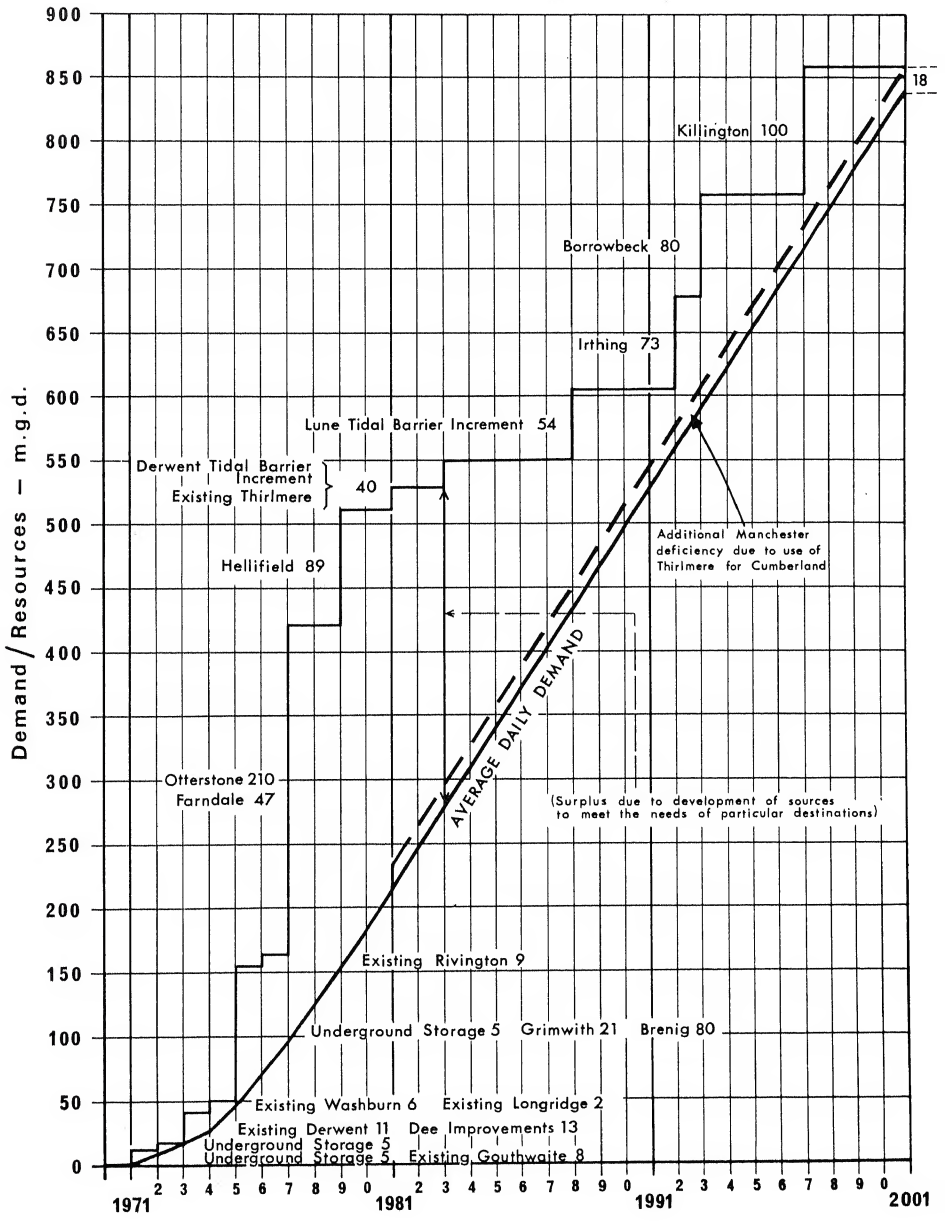
DEMAND / RESOURCES DEVELOPMENT

Programme no. 5a
Seven Large Inland Sources



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ACTUAL AND DISCOUNTED ANNUAL EXPENDITURES

(CAPITAL, MAINTENANCE AND OPERATION)

Programme no. 5a – Seven Large Inland Sources

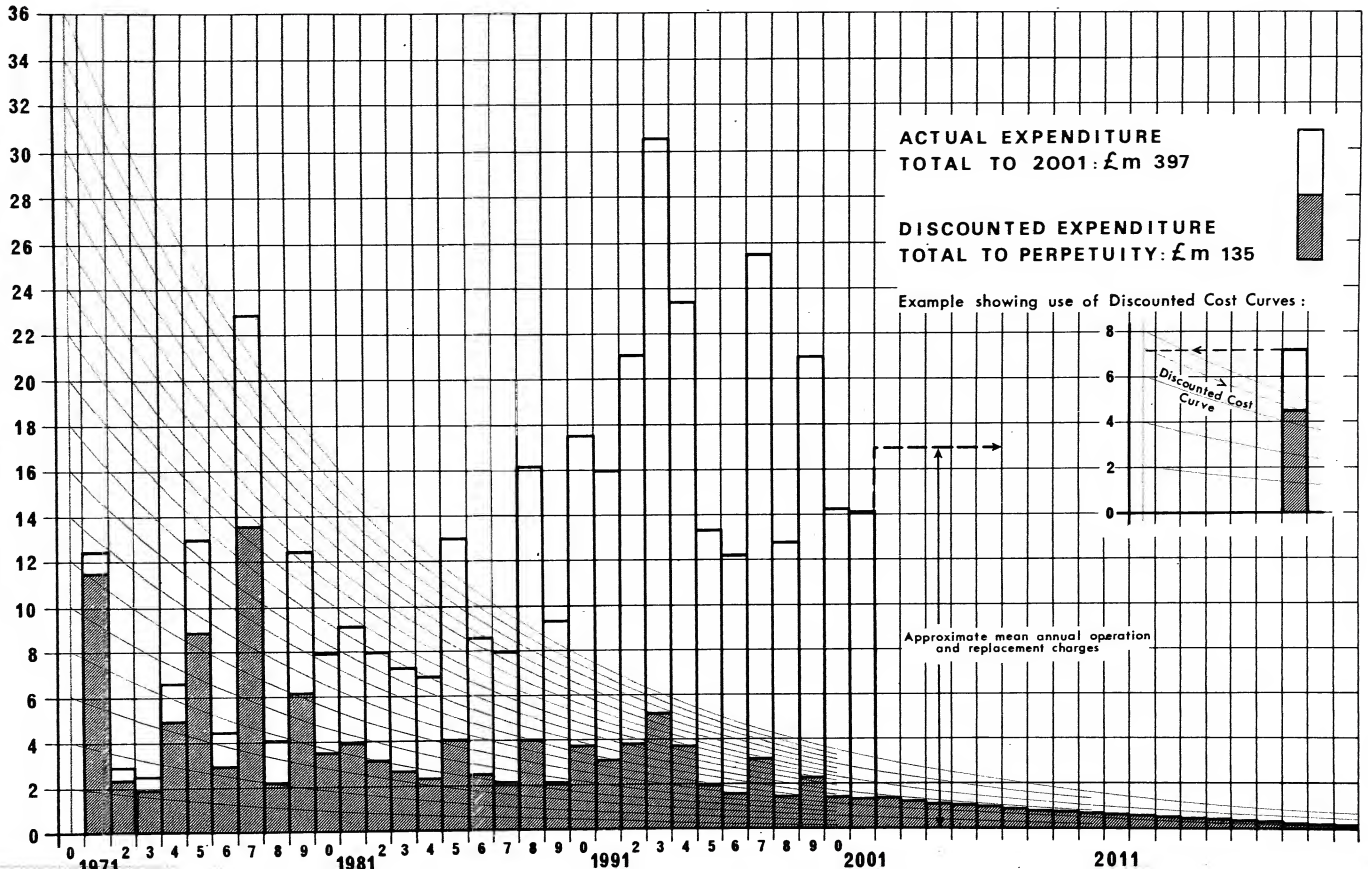

Fig.c

WATER RESOURCES BOARD

REPORT ON WATER RESOURCES IN THE NORTH

3°0 4°0 5°0 6°0

NORTHUMBERLAND COAST

NORTHUMBERLAND

BERWICK-UPON-TWEED

Tweed Till Aln Coquet Rede N. Tyne Wansbeck

OTTERSTONE B6

IRTHING B6

1

NEWCASTLE-UPON-TYNE TYNEMOUTH SOUTH SHIELDS SUNDERLAND

A3

SOLWAY FIRTH

SOLWAY COAST

CARLISLE Eden Wampool Waver Caldew Petteril

27

DERWENT Derwent Browney Wear

WITTON-LE-WEAR D 17

COW GREEN

MIDDLETON D 18

WEST HARTLEPOOL

WORKINGTON TIDAL SLUICE B7

WORKINGTON

BASSENTHWAITE CONTROL B2

Penrith

D19 MARRON

WHITEHAVEN

THIRLMERE B1

HAWES WATER C11

BALDERHEAD Greta

MIDDLESBROUGH Tees

NORTH YORK MOORES Whitby Esk Leven

BORROW BECK C10

KILLINGTON C9

LAKE DISTRICT

C15 Lune Rib Kent Sprint Mint Winster Leven Bela

C14 Wiske

FARNDALE A1

YORKSHIRE DALES Ure

SCARBOROUGH

Derwent Rye

BISHOPDALE D3

C13 Skell

BARROW-IN-FURNESS

LUNE TIDAL SLUICE C12

LANCASTER

MORECAMBE AND HEYSHAM

MORECAMBE BAY (under investigation)

HELLIFIELD C8

STOCKS RESERVOIR

Lune

GRIMWITH A2

GOUTHWAITE Nidd

HARROGATE

Skipton

Wharfe Ouse

2

YORK

Hull Derwent

FOREST OF BOWLAND

Ribble Calder

BLACKPOOL

26

PRESTON

BURNLEY

BRADFORD

LEEDS

DERWENT TIDAL SLUICE A7

KINGSTON UPON HULL

River Authorities

1 NORTHUMBRIAN
2 YORKSHIRE OUSE AND HULL
24 DEE AND CLWYD
25 MERSEY AND WEAVER
26 LANCASHIRE
27 CUMBERLAND

Existing Reservoir

Existing Reservoir (extended or changed use)

Reservoir Site

Alternative Site

Regulated River

Inter-river Link

Transmission Link

River Authority Boundary

National Park

Area of Outstanding Natural Beauty

Selected County Boroughs — BURNLEY

Selected Municipal Boroughs — WREXHAM

Selected Urban Districts — Rhyl

Population Density
Over 6400 per square mile

Height in Feet and Metres

Feet	Metres
1400	427
600	183
0	0

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CHAPTER 1

INTRODUCTION

1. We have undertaken three major regional surveys designed to assess the probable demand for water in England and Wales up to the end of this century and to indicate how it can be met. We reported on South-East England in 1966[1]; the present report deals with the North of England and North Wales; and we hope to report next year on Wales and the Midlands.

2. This report overtakes our interim report on the North, published in 1967[2]. It deals with those parts of England and Wales contained within the areas of the Cumberland, Northumbrian, Yorkshire Ouse and Hull, Lancashire, Mersey and Weaver, and Dee and Clwyd River Authorities. The area of the Dee and Clwyd River Authority will also be included in our report on Wales and the Midlands; it is included in the present report because of its importance for the Liverpool Corporation Water Undertaking and the Wirral Water Board. This report therefore covers the whole of Cumberland, Westmorland, Northumberland, Durham, Yorkshire, Lancashire and Cheshire; most of Flintshire; parts of Denbighshire, Merionethshire, and fringe areas in Shropshire, Staffordshire and Derbyshire.

3. Preliminary studies of the possibilities of estuary storage in Morecambe Bay, the Dee Estuary and Solway Firth were published in 1966-7[3]. In Morecambe Bay and the Dee Estuary further studies of feasibility and cost are now in progress, and reports on these should be available in 1971. There is also a wide range of potential inland resources in the region. The choice, for the long term, between the various alternative sources of supply can be made only when the estuary studies are complete. But an assessment of the inland resources is required now, so that (i) short-term developments for the next ten years can be selected which will not prejudice long-term planning to the end of the century, and (ii) the physical suitability of sites for possible long-term development may be investigated in good time for the major decisions which will need to be taken from 1972 onwards. This report provides such an assessment.

---

1. *Water Supplies in South-East England: H.M.S.O. 1966.*
2. *Interim Report on Water Resources in the North: H.M.S.O. 1967.*
3. *Morecambe Bay Barrage: Desk Study: Report of Consultants; Solway Barrage: Desk Study: Report of Consultants; Morecambe Bay and Solway Barrages: Report on Desk Studies; Dee Crossing Study Phase 1. H.M.S.O. 1966-7.*

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It also makes some comparisons based on the preliminary studies of estuary storage. We hope that it will give the river authorities a firm basis for action in the period before the major decisions for the future can be taken. We intend to discuss it not only with the river authorities but also with organisations representing water users and other interests.

4. As in our survey of South-East England, a Technical Working Party was established to assess demands and resources in the region. Its members were the Chief Engineers of the river authorities; representatives of the corresponding Area Committees of the British Waterworks Association; representatives of the Central Electricity Generating Board, the British Waterways Board and the Ministry of Housing and Local Government; and members of our staff. Their report[1], which is published separately, has formed the basis of our own report, and we refer frequently to it in the following chapters. We are grateful to the Working Party for their lucid, painstaking and comprehensive work.

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1. *Water Resources in the North: Report of the Northern Technical Working Party: H.M.S.O. 1970.*

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CHAPTER 2

DEMAND

Public Water Supply

5. The Working Party's assessment of future demand on the public water supply is based on estimates which the 82 statutory water undertakings in the region have prepared either by extrapolating the trends of total demand or by applying per capita demand trends to expected population growth. Special allowance is made for planned growth, as at the new town in central Lancashire and on Humberside. We accept these estimates as a suitable basis for planning.

6. Industry makes proportionately higher demands on the public supply in this region than elsewhere. The per capita consumption is consequently higher than the national average and is expected to remain so: it was 62 gallons per day (278 litres per day) in 1967 and is expected to rise to 100 gallons per day (455 litres per day) by the year 2001. The corresponding figures for the South East region are 56 and 80 gallons per day (254 and 363 litres per day). The total demand on the public water supply is expected to rise from 916 million gallons per day (m.g.d.) (4 160 000 cubic metres per day (m^3/d))[1] in 1967 to 1,376 m.g.d. (6 255 000 m^3/d) in 1981 and 1,922 m.g.d. (8 740 000 m^3/d) in 2001. These totals include the following demand by industry on the public water supply: 400 m.g.d. (1 820 000 m^3/d) in 1967, 660 m.g.d. (3 000 000 m^3/d) in 1981 and 940 m.g.d. (4 270 000 m^3/d) in 2001. These estimates represent an average growth rate to 2001 of 3.2% of the 1967 figure (compared with 3.1% for the South-East), or a compound rate of 2.2%.

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1. *Throughout this report all metric quantities are the approximate equivalents rounded off to the nearest thousand or 5 thousand cubic metres as appropriate.*

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7. Table A shows the estimated future demand on the public water supply undertakings, their present resources, and the deficiency which will need to be made good.

TABLE A

PUBLIC WATER SUPPLY

DEMANDS AND DEFICIENCIES

River Authority Area	Average Daily Demand (m.g.d.)			Authorised Resources (including imports) m.g.d.	Deficiency (nearest 5 m.g.d.)[1]	
	1967 (1)	1981 (2)	2001 (3)	(4)	1981 ((2)-(4))	2001 ((3)-(4))
Northumbrian	185	293	417	250	45	165
Yorkshire Ouse & Hull	239	329	470	280	55	190
Dee & Clwyd	23	41	58	33	10	25
Mersey & Weaver	340	490	660	438	65	225
Lancashire	102	158	224	120	40	105
Cumberland	27	65	93	44	20	50
Total	916	1,376	1,922		235	760
Lincolnshire[2] (Humberside)	-	30	100		30	100
Overall Total	916	1,406	2,022	1 165	265	860

1. *Disregarding any unused surpluses.*

2. *These estimates allow for the possible need to export water from the area of the Yorkshire Ouse and Hull River Authority to meet demands arising in north Lincolnshire, or north and south of the Humber as a result of the planned growth of a Humberside conurbation.*

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TABLE A

PUBLIC WATER SUPPLY

DEMANDS AND DEFICIENCIES

METRIC EQUIVALENTS

thousands of cubic metres per day

River Authority	Average Daily Demand			Authorised Resources (Including Imports) (4)	Deficiency (nearest 5 000 m^3/d)[1]	
	1967 (1)	1981 (2)	2001 (3)		1981 ((2)-(4))	2001 ((3)-(4))
Northumbrian	840	1 335	1 890	1 138	205	750
Yorkshire Ouse & Hull	1 089	1 495	2 140	1 272	250	865
Dee & Clwyd	105	187	264	152	45	115
Mersey & Weaver	1 545	2 230	3 000	1 997	295	1 025
Lancashire	464	716	1 018	546	180	475
Cumberland	123	296	423	201	90	230
Total	4 166	6 295	8 735		1 065	3 550
Lincolnshire[2] (Humberside)	-	135	455		135	455
Overall Total	4 166	6 394	9 190	5 306	1 200	4 005

1. *Disregarding any unused surpluses.*

2. *These estimates allow for the possible need to export water from the area of the Yorkshire Ouse and Hull River Authority to meet demands arising in north Lincolnshire, or north and south of the Humber as a result of the planned growth of a Humberside conurbation.*

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Direct Industrial and Agricultural Demand

8. In addition to the 400 m.g.d. (1 820 000 m^3/d) which it presently obtains from the public water supply, industry makes substantial direct abstractions. The total quantity of water authorised to be abstracted by industry (excluding the Central Electricity Generating Board) at 30th September 1967 was 2,700 m.g.d. (12 275 000 m^3/d); over 80% of this is authorised by three river authorities - Northumbrian, Yorkshire Ouse and Hull and Mersey and Weaver. This total is more than three times larger than that in the South-East; the total quantity authorised for abstraction by agriculture, in contrast, is only one-eighth of that in the South-East. Agricultural abstractions may, however, be locally important in parts of Lancashire, Cheshire and Yorkshire.

9. Table B shows the numbers of licences and the quantities of water authorised to be abstracted for use in industry and agriculture, including spray irrigation, from surface and underground sources at 30th September 1967.

TABLE B

AUTHORISED ABSTRACTIONS — INDUSTRY AND AGRICULTURE

River Authority	Industry		Agriculture (Including Spray Irrigation)	
	No. of Licences	Amounts Authorised to be Abstracted m.g.d.	No. of Licences	Amounts Authorised to be Abstracted m.g.d.
Cumberland	98	107 (486)	242	0.4 (2)
Lancashire	419	290 (1 320)	568	12.0 (55)
Northumbrian	168	455 (2 068)	905	2.9 (13)
Yorkshire Ouse & Hull	1,263	973 (4 423)	2,134	7.5 (34)
Dee & Clwyd	81	106 (481)	42	0.5 (2)
Mersey & Weaver	347	769 (3 496)	660	1.5 (7)
Totals: Northern River Authorities	2,376	2,700 (12 274)	4,551	25 (113)
S.E. River Authorities	2,059	874 (3 973)	11,921	200 (909)

NOTE: Figures in brackets are metric equivalents in thousands of cubic metres per day.

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10. In addition to these amounts the Central Electricity Generating Board is authorised to abstract 4,300 m.g.d. (19 548 000 m^3/d) mostly as cooling water for power stations. Most of this is for "through cooling" in which almost all the water is returned to the river, though at a higher temperature, and which is possible only at sites where large flows are readily available. At other sites, and these will include almost all future sites where fresh water is to be used for cooling, water is re-circulated through cooling towers, leading to a loss of water by evaporation, and thus a demand.

11. These figures for authorised abstractions do not provide a basis for planning future development of resources since they do not allow for the effect of the re-use of water at successive points on a watercourse (i.e. abstraction, discharge as effluent, and subsequent abstraction further downstream). What is needed is a detailed analysis of the needs of riparian industry in relation to the resources of each watercourse, taking account of water quality and temperature and of both abstractions and discharges; and we agree with the Working Party that such analyses will be a continuing task for the river authorities.

12. In the absence of such detailed analyses, the Working Party define two broad categories of industrial area. The first category consists of industrialised river valleys, where the growth of abstraction may be expected to be balanced by the growth of discharge. We accept the Working Party's conclusion that in these valleys - principally those of the Aire, Calder, Don, Mersey and Ribble - new industrial demand, including that for power stations, is likely to be met by additions of public sewage effluents, and that future power stations with fresh water cooling systems will be sited in these valleys. But to maintain this balance between demand and supply requires careful control over the location of both abstractions and discharges; and we return to this point later (paragraph 33).

13. The second category consists of industrialised areas on the coast and on estuaries, where there is little or no opportunity for re-use of water. In this category the Working Party allow for increases in demand equivalent to an annual rate of about 4%; and on this basis they forecast a net deficiency of supplies for direct industrial and agricultural abstraction amounting to about 45 m.g.d. (200 000 m^3/d) in 1981 and 105 m.g.d. (475 000 m^3/d) in 2001.

14. Table C summarises the situation described in the foregoing two paragraphs. Where no deficiency is forecast, either the growth of demand is expected to be balanced by the growth of effluent or - as in Cumberland and on Humberside - generous allowance has been made in the estimates for public water supply.

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TABLE C

DIRECT INDUSTRIAL AND AGRICULTURAL ABSTRACTION:

DEFICIENCIES

River Authority	Net Deficiency - nearest 5 m.g.d.			
	1981		2001	
Northumbrian	20	(90)	40	(180)
Yorkshire Ouse & Hull	-	-	-	-
Dee & Clwyd	15	(70)	30	(135)
Mersey & Weaver	5	(20)	15	(70)
Lancashire	5	(20)	20	(90)
Cumberland	-	-	-	-
Lincolnshire (Humberside)	-	-	-	-
Total Deficiency	45	(200)	105	(475)

NOTE: Figures in brackets are metric equivalents in thousands of cubic metres per day

15. The foregoing estimates thus show an overall excess of demand over supply in the region of 310 m.g.d. (1 400 000 m^3/d) in 1981 and 965 m.g.d. (4 390 000 m^3/d) in 2001. The total deficiency is shown by river authority areas in Table D: these figures represent the total additional amounts of water which will be needed by these dates.

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TABLE D

THE TOTAL DEFICIENCY

(nearest 5 m.g.d.)

River Authority	Public Water Supply Deficiency		Direct Industrial and Agricultural Abstraction Net Deficiency		Total Deficiency	
	1981	2001	1981	2001	1981	2001
Northumbrian	45	165	20	40	65	205
Yorkshire Ouse & Hull	55	190	-	-	55	190
Dee & Clwyd	10	25	15	30	25	55
Mersey & Weaver	65	225	5	15	70	240
Lancashire	40	105	5	20	45	125
Cumberland	20	50	-	-	20	50
Total	235	760	45	105	280	865
Lincolnshire[1] (Humberside)	30	100	-	-	30	100
Overall Total	265	860	45	105	310	965

1. *These estimates allow for the possible need to export water from the area of the Yorkshire Ouse and Hull River Authority to meet demands arising in north Lincolnshire, or north and south of the Humber as a result of the planned growth of a Humberside conurbation.*

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TABLE D

THE TOTAL DEFICIENCY

METRIC EQUIVALENTS

thousands of cubic metres per day

River Authority	Public Water Supply Deficiency		Direct Industrial and Agricultural Abstraction Net Deficiency		Total Deficiency	
	1981	2001	1981	2001	1981	2001
Northumbrian	205	750	90	180	295	930
Yorkshire Ouse & Hull	250	865	-	-	250	865
Dee & Clwyd	45	115	70	135	115	250
Mersey & Weaver	295	1 025	20	70	315	1 095
Lancashire	180	475	20	90	200	565
Cumberland	90	230	-	-	90	230
Total	1 065	3 550	200	475	1 265	3 935
Lincolnshire[1] (Humberside)	135	455	-	-	135	455
Overall Total	1 200	4 005	200	475	1 400	4 390

1. *These estimates allow for the possible need to export water from the area of the Yorkshire Ouse and Hull River Authority to meet demands arising in north Lincolnshire, or north and south of the Humber as a result of the planned growth of a Humberside conurbation.*

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CHAPTER 3

RESOURCES

Rainfall

16. The region includes the Lake District, with the heaviest rainfall in the whole of England and Wales, and on the east coast some of the drier areas of the country. Within a distance of about 70 miles (110 km) the average annual rainfall varies from 180" (4 570 mm) to 25" (635 mm). The average annual rainfall and run-off for each river authority area is given in Table E.

TABLE E

AVERAGE ANNUAL RAINFALL AND RUN-OFF

River Authority	Rainfall		Run-off	
	ins	mm.	m.g.d.	Thousands of cubic metres per day
Northumbrian	34.9	885	2,800	12 730
Yorkshire Ouse & Hull	32.9	836	3,900	17 730
Dee & Clwyd	42.6	1 080	1,200	5 450
Mersey & Weaver	37.6	955	1,500	6 820
Lancashire	56.4	1 435	3,200	14 550
Cumberland	51.5	1 310	2,600	11 820
	Average: 42.6	1 083	Total: 15,200	69 100

In this context run-off means the residual rainfall left after deducting estimated losses due to evaporation: over most of the region these losses vary from about 18" (457 mm) to 14" (356 mm) per annum.

17. Six of the ten National Parks in England and Wales lie wholly or partly within the region, occupying some 2,800 square miles (7 250 km^2) or 18% of its total area of 15,500 square miles (40 000 km^2). We estimate that the rain falling on the National Parks in the region accounts for 5,000 m.g.d. (22 730 000 m^3/d) or 33% of the total run-off of 15,200 m.g.d. (69 100 000 m^3/d).

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The River Systems

18. The region contains no single river basin dominated by a major river such as the Severn, Thames or Trent, but rather a large number of smaller rivers with markedly diverse pollution characteristics. It includes some of the cleanest rivers in the country; and also, for instance in the Calder and Don in Yorkshire and Calder and Mersey in Lancashire, some of the dirtiest, which are unlikely for some time to be of value for public water supply purposes.

19. The Working Party examine how water resources can be developed on a regional scale by the regulation of the cleaner river systems and by using them to convey water over substantial distances; for example, the South Tyne may form a useful link from west to east, and the Swale from north to south. This use of rivers will require careful control of pollution.

20. Before relating these possible regional developments to demands, the Working Party consider what supplies could be provided by transferring local surpluses and by the use of what they call 'isolated' sources. These are sources which are convenient for a local user but not suitable for integration into a regional pattern; they include the remaining sources in the industrialised river basins of south Yorkshire, south Lancashire and Cheshire. Such 'isolated' sources could provide 225 m.g.d. (1 020 000 m^3/d) by the end of the century; the Working Party conclude that 125 m.g.d. (570 000 m^3/d) of this is worth developing in preference to more remote sources. We refer again to this in paragraph 57. The total deficiency of 965 m.g.d. (4 390 000 m^3/d) set out in Table D may thus be reduced by 125 m.g.d. (570 000 m^3/d). The effect by river authority areas is shown in Table F. The resulting final deficiencies of 215 m.g.d. (1 970 000 m^3/d) in 1981 and 840 m.g.d. (3 820 000 m^3/d) in 2001 remain to be met by integrated regional programmes of development.

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TABLE F

ISOLATED SOURCES

(nearest 5 m.g.d.)

River Authority	Total Deficiency (Table D)		Isolated Sources			Final Net Deficiency	
			Total Potential	Assumed Development			
	1981	2001		1981	2001	1981	2001
Northumbrian	65	205	30	15	15	50	190
Yorkshire Ouse & Hull	55	190	40	15	25	40	165
Dee & Clwyd	25	55	5	-	-	25	55
Mersey & Weaver	70	240	80	35	60	25[1]	180
Lancashire	45	125	20	10	10	35	115
Cumberland	20	50	50	10	15	10	35
Lincolnshire (Humberside)	30	100	-	-	-	30	100
Total	310	965	225	85	125	215[1]	840

1. *After allowing for transfer of existing surpluses.*

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TABLE F

ISOLATED SOURCES

METRIC EQUIVALENT

thousands of cubic metres per day

River Authority	Total Deficiency (Table D)		Isolated Sources			Final Net Deficiency	
			Total Potential	Assumed Development			
	1981	2001		1981	2001	1981	2001
Northumbrian	295	930	135	70	70	225	860
Yorkshire Ouse & Hull	250	865	180	70	115	180	750
Dee & Clwyd	115	250	20	-	-	115	250
Mersey & Weaver	315	1 095	365	160	270	115[1]	825
Lancashire	200	565	90	45	45	155	520
Cumberland	90	230	230	45	70	45	160
Lincolnshire (Humberside)	135	455	-	-	-	135	455
Total	1 400	4 390	1 020	390	570	970[1]	3 820

1. *After allowing for transfer of existing surpluses.*

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Regional Resources: River Regulation

21. The Working Party considered what additional supplies could be developed from the river system mainly by using surface storage to regulate river flows. Their conclusion was that in this way an additional supply of 2,250 m.g.d. (10 230 000 m^3/d) could be developed without allowing anything for re-use. The disposition of these supplies within the river authority areas is shown in Table G below.

TABLE G

REGIONAL RESOURCES

River Authority	Yield	
	m.g.d. (to the nearest 50)	Thousands of cubic metres per day
Northumbrian	500	2 275
Yorkshire Ouse & Hull	400	1 820
Dee & Clwyd	150	680
Mersey & Weaver	-	-
Lancashire	750	3 410
Cumberland	450	2 045
Total	2 250	10 230

Ground Water

22. There are ground water sources in, for example, east Yorkshire, Lancashire and Cheshire, Durham, west Cumberland, and the Vale of Eden. Some of those in Lancashire should be developed, in conjunction with surface run-off, to help to meet short term demands. But underground storage is unlikely to contribute substantially to supplies in this region as a whole in the long term.

Existing Development

23. In the west of the region, Manchester and Liverpool dominate the existing water resource developments for the public supply. In the last 70 years the Manchester Corporation have developed a system of aqueducts which convey the yield of their Lake District sources, about 140 m.g.d. (635 000 m^3/d), from the

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area of the Cumberland River Authority through that of the Lancashire River Authority to that of the Mersey and Weaver River Authority. In the same period the Liverpool Corporation have developed sources in North Wales: Lake Vyrnwy on the Severn, from which an aqueduct conveys 45 m.g.d. (205 000 m^3/d) direct to Merseyside, and more recently the Llyn Celyn project, which in conjunction with the Bala control system enables up to 64 m.g.d. (290 000 m^3/d) to be abstracted from the Dee near Chester and pumped to the city.

24. Other water supply undertakings have developed local sources in the Pennines, and in some cases supplement these by bulk supplies from the major aqueducts. The Fylde Water Board are developing an integrated system of surface and ground-water supplies, and further investigation is in progress. The Cheshire water undertakings abstract water from the regulated River Dee in conjunction with their original ground-water sources.

25. In the east of the region, in the area of the Northumbrian River Authority the three major conurbations based on the estuaries of the Tyne, Wear and Tees obtain their supplies very largely from those rivers and the storage reservoirs on them or their tributaries.

26. In the industrial area of Yorkshire, water is obtained from a large number of reservoirs in the Pennines on the Yorkshire Ouse river system, supplemented by bulk supplies from the Derwent Valley Water Board whose reservoirs are outside the region on the headwaters of the Derbyshire Derwent. Abstraction from the Yorkshire Derwent, to supply Sheffield, Leeds, Barnsley and Rotherham, is a recent development. The proposed regulating reservoir at Farndale and tidal sluices in the river will allow the distribution of more water from the Yorkshire Derwent to the East and West Ridings and perhaps south Humberside.

Re-use of water

27. It was noted in Chapter 2 that industry in the North obtains the bulk of its water supplies by direct abstraction from rivers or underground sources (Table B). Most of these abstractions are located in industrialised river valleys where water is used and re-used many times.

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28. In their assessment of future industrial demands the Working Party assume that this repeated re-use can continue, and that new discharges of sewage effluent resulting from the growth in public water supply consumption will offset the growth of industrial demand on these rivers. Their necessarily simplified approach to a complex problem leads them to the conclusion that over 300 m.g.d. (1 365 000 m^3/d) of new net industrial demand will be met by new discharges of sewage effluent. If new net demand of this magnitude had to be met by the development of additional resources it could involve capital expenditure of the order of £100 million and substantial use of land for reservoir storage.

29. We accept the Working Party's conclusion; and we consider that re-use is essential to the efficient provision from these rivers of future industrial supplies.

The Importance of Quality

30. The quality of water in rivers which provide the public supply must obviously be maintained. But quality is also of vital importance for industrial water supplies, particularly where re-use is involved.

31. In our Report[1] on the South-East we drew attention to the serious effects of industrial wastes and the importance of appropriate research. The views we there expressed are also relevant here. In the North industrial abstractors will be the most substantial re-users of water, and the problems of treating their effluents are likely to be more acute than in the South-East. We are glad to note that the disposal of toxic wastes is being examined by a committee representative of the interests concerned, and sewage disposal questions by a working party under the chairmanship of Mrs. Lena Jeger, M.P., and that river pollution is being surveyed by the Ministry of Housing and Local Government in co-operation with the river authorities.

32. Some of the rivers of the North of England may require programmes of research comparable with that on the uses of the River Trent in which we are currently engaged with the Trent River Authority, the Ministry of Housing and Local Government, and the Water Pollution Research Laboratory.

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1. *Water supplies in South-East England: paragraph 34.*

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33. The best use of water resources requires efficient river management and the control and planning of repeated uses of water. We consider that control not only of the quality but also of the location of effluent discharges is essential to safeguard future supplies and, in particular, to avoid increasing transfer of industrial demands to the public water supply. The present administrative structure gives the river authorities, who are responsible for river management, only limited powers for the control of effluent discharges and none for planning their location. Without such powers the maximum benefit cannot be derived from the integrated operation of river systems.

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CHAPTER 4

PROGRAMMES OF DEVELOPMENT

Demand Districts

34. In order to present their assessment of the demand for water in the region, the Working Party define thirteen 'demand districts' comprising groupings of statutory water undertaking areas and based mostly on existing conurbations. The needs of each district are represented by the sum of the component needs within it at a notional delivery point at the centre of gravity of demand. Thus the costs of developing alternative sources, treating the water and delivering it to representative destinations throughout the region may be compared. The river authority areas would have been too large a unit for this purpose and the existing delivery points at the undertakings' service reservoirs too numerous to permit simple analysis and presentation.

The problem of choice

35. It is evident that there is no shortage of water in the North. As Table G shows, the potential resources far exceed estimated demand in the region to the end of the century. The problem is one of making the right choice of projects to be developed during this period and developing them in the right order.

36. This is not to say, of course, that even from this array of possible sources of supply it is possible to select a programme of development free from objections As the Working Party point out in Chapter 6 of their report, inevitably some of the projects with most technical advantages for further storage would encroach on the national parks where development should be considered with special care; some include developments in other localities which may be held in higher regard than individual sites within the parks; some affect farming or forestry. The interests of farming or forestry can be partly quantified in terms of land or produce value, and the Working Party allow for this in estimating costs. But there are other factors which must be recognised although they are more difficult to quantify: these the Working Party well describe as disturbance to the rural scene, the loss of livelihood and sense of security of those earning their living from the land, and the resulting feeling that rural interests are being sacrificed to the appetites of urban civilisation.

37. We endorse the Working Party's views in their valuable Chapter 6 and accept their practical approach to the problem of measuring the differences in these

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respects between one site and another, by giving data in such a form that the cost of including or excluding any particular project can be demonstrated.

Alternative Programmes

38. From a multiplicity of choices the Working Party set out ten possible programmes of development in which selected regional sources are brought into service and linked with the demand districts, where possible by river, but elsewhere by pipeline, to meet the predicted needs of 215 m.g.d. (970 000 m^3/d) by 1981 and 840 m.g.d. (3 820 000 m^3/d) by 2001. The programmes have different specifications: one provides the cheapest overall solution; one excludes all development in National Parks; the others combine different types and numbers of sources. Each programme provides the cheapest regional solution available within its own specification.

39. The programmes include the costs of constructing, maintaining and operating storage works, strategic aqueducts, treatment works and terminal storage, but do not include the costs of distributing water within demand districts. Allowance has, however, been made for the special treatment needs of particular districts.

40. The Working Party's approach is thus essentially a regional one, where the role of any particular source is not necessarily the same throughout the period under consideration. This approach enables the resources of the region to be developed and deployed in the most flexible and economical manner.

41. We consider here the ten basic programmes set out by the Working Party; their essentials are given in Table H. Table J sets out for each programme, at ten-year intervals until the end of the century, the number and surface area of reservoirs it requires. One unacceptable item in any programme does not lead us to reject that programme as a whole, since acceptable alternatives to the item concerned may be found; in some cases these have been indicated.

42. For each programme the Working Party calculate the 'present value' of all estimated future costs; that is to say, the equivalent of all future costs discounted back to the year 1970, normally at 8% interest. These equivalents (described in Table H as the "1970 value" of a programme) should be used in comparing the effective costs of programmes, since they take into account the timing of future capital expenditure and running costs as well as their total

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sum and thus reflect the burden of programmes in which heavy costs are incurred early with some works under-employed for many years. Both the 1970 values and the simple sum of programme costs (described as 'total outlay') are given in Table H; the following paragraphs refer only to 1970 values.

43. The Working Party also give variations on these programmes to allow for two opposite possibilities. One is that water may not need to be exported from the region to a new conurbation on Humberside. The other is that substantial exports may be required to the West Midlands or the South. Neither variation appears to affect the relative merits of the different types of regional programme in such a way as to influence the choice between them; we therefore defer considering these variations further until we have completed our study of Wales and the Midlands.

44. The Working Party also consider how substantial changes in the assumed pattern of future demand, or in future movements of prices and interest rates, might affect the relative merits of the programme; and they conclude that the order of merit would not change.

Programme No. 1

45. Programme No. 1 consists of the development of surface sources by means of direct supply reservoirs. This would follow the traditional pattern of development, but would be expensive and would require extravagant use of land. It would require a total of 41 reservoirs, 25 of them in National Parks or designated Areas of Outstanding Natural Beauty, and would use 22,500 acres (9 100 km^2) of land. It is included by the Working Party for the purposes of comparison with other programmes of development. We have found it useful for this purpose, but we do not accept it as a suitable pattern of development.

Programme No. 2

46. Programme No. 2 embodies the cheapest solution put forward by the Working Party. It would require 17 regulating reservoirs, including 10 in National Parks or Areas of Outstanding Natural Beauty, and would use 14,500 acres (58.6 km^2) of land - more than any other except Programme No. 1. It is unlikely that such a programme would prove acceptable on any grounds other than those of cost, but it is useful for comparison and provides some measure of the additional expense involved in seeking alternative sources.

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Programme No. 3

47. Programme No. 3 excludes all reservoir sites in National Parks and Areas of Outstanding Natural Beauty, except for the reservoir which is urgently required at Farndale. It calls for two fewer reservoirs than Programme No. 2 and slightly less land (14,000 acres (56.7 km^2)) but is 9% more expensive in 1970 values. However, it takes no account of the intrinsic amenities of any of the reservoir sites. Scenically attractive sites are by no means confined to the National Parks; and the programme includes sites outside the Parks where a reservoir might be considered an unacceptable intrusion.

Programme No. 4: Manchester

48. Manchester is unique among the major conurbations of England and Wales in that it still uses no water drawn from the middle or lower reaches of rivers but depends entirely on upland gathering grounds. Moreover, because of Manchester's geographical situation, the normal economies of conveying supplies by river, rather than by pipeline, do not apply. For these reasons the Working Party give special attention to the view expressed by Manchester Corporation Waterworks that industry in the area is accustomed to a particular quality of water and that this should be maintained.

49. Programme No. 4 is a modification of Programme No. 3 designed to give Manchester a supply piped directly from a reservoir at Killington while the remainder of the North relies on supplies from regulated rivers. This though using less land (13,500 acres (54.7 km^2)), involves an increase in cost of nearly 4% over Programme No. 3 or about 13% over the cheapest programme, No. 2. More important, if Manchester is to have a direct upland supply it would rule out the use of estuary sources for Manchester and might therefore preclude the estuary programmes.

Programme No. 5

50. Programme No. 5 has the great merit of reducing the disturbance caused by reservoir development by concentrating it in a small number of large new reservoirs (12,500 acres (50.6 km^2) of land). Its cost is much the same as Programme No. 4, at 12% more than Programme No. 2. We consider that this type of programme provides an acceptable solution in principle, but we do not wholly agree with the Working Party's choice of sites, and in our Chapter 6 we put

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forward a modified Programme 5A. The advantages of a programme of this type can be obtained only on the basis of a regional plan and of extensive collaboration by all the organisations concerned in implementing it.

Programmes Nos. 6 and 7

51. Programmes Nos. 6 and 7 rely as far as possible on the development of storage in estuaries in order to minimise land use. In these cases the Working Party assume that estuary storage could be available for use in 1981 and could provide for all needs after that date, that is for about 75% of all the extra yield required to the end of the century. The remaining 25% would be met by the inland sources required by 1981. The cost is some 20% more than that of Programme No. 2; and because of the dominant effect of transmission costs, the development of three estuary schemes rather than two has little effect on the comparative costs of the programme.

Programmes Nos. 8, 9 and 10

52. Programmes Nos. 8, 9 and 10 make less use of estuary storage, and incorporate inland schemes for those areas which are most expensive to supply from the estuaries on the west coast. In Programmes Nos. 8 and 9, which make use of Morecambe Bay and the Dee Estuary or Morecambe Bay alone to meet about 55% of the total demand, the costs are respectively 17% and 18% more than those of Programme No. 2. Programme No. 10, which makes use of the Dee Estuary only to meet about 30% of the total demand, costs 9% more than Programme No. 2.

Estuary Development

53. Of the basic programmes incorporating estuary development there are only marginal differences in costs in 1970 values between Programmes Nos. 6, 7, 8 and 9, requiring, respectively, works in the Dee, Morecambe Bay and Solway; or Morecambe and Solway; or at Dee and Morecambe with some major inland reservoirs; or at Morecambe alone with some major inland reservoirs. Programme No. 10, which combines development of the Dee Estuary with major inland reservoirs, costs appreciably less than the others, but would meet only a small part of the total demand from estuary storage. With this exception there appear to be no substantial differences in cost between programmes incorporating one, two or three estuary schemes.

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54. None of the estuary storage schemes is, on the most optimistic assumptions, likely to be available before the late 1970's. No firm decisions can be made about programmes incorporating them until the feasibility studies now in progress have been completed.

55. The Working Party point out that the costs used for estuary works in their analyses are the tentative ones provided by the desk studies and are therefore necessarily less reliable than the estimated costs of inland works. Moreover, the Working Party could not take into account the supplementary benefits and disadvantages which must be considered in reaching any final judgment on estuary schemes. There are difficulties in measuring the benefits which may accrue, in particular the less tangible gains to amenity and recreation. Problems also arise from the different conventions in use in certain of the fields concerned, notably in the methods of converting expected future benefits to present values. When these problems are resolved it is possible that the value of these benefits will influence not only the choice of the form of water storage development in a given estuary but also the choice between estuary programmes and inland programmes.

Conclusion

56. With these reservations, we consider that these programmes provide a proper basis for choices of future general strategy. In the next chapter we discuss some of their detailed implications.

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TABLE H

BASIC PROGRAMMES OF DEVELOPMENT PROVIDING 840 m.g.d. AT 2001

SCHEDULE OF SOURCES

1	2	3	4	5	6	7	8	9	10	11	12	13
River Authority	Reservoir or Site	SOURCES DEVELOPED AND REQUIRED YIELD IN EACH PROGRAMME (m.g.d.)										
		Programme No.										
		1	2	3	4	5	6	7	8	9	10	5A[1]
Various	Changes of use of existing sources	Total of 41 Inland Reservoirs	64	64	64	64	64	64	64	64	64	86[2]
Northumbrian	Otterstone		-	163	163	210	39	39	184	94	74	210
"	Witton-le-Wear		91	91	91	89	-	-	-	91	91	-
"	Middleton		79	80	80	80	-	-	-	-	80	-
Yorkshire Ouse & Hull	Grimwith[3]		21	-	-	-	-	-	-	-	-	21
" "	Farndale		-	47	47	47	47	47	47	47	47	47
" "	Arkle Beck		44	-	-	-	-	-	-	-	-	-
" "	Bishopdale		45	-	-	-	-	-	-	-	-	-
" "	Birkby Nab		-	30	30	-	-	-	-	-	30	-
" "	New Gouthwaite[3]		24	24	24	-	12	9	12	9	24	-
Dee & Clwyd	Clwyd Tube Wells		3	3	3	3	3	3	3	3	3	-
"	Brenig		80	80	80	80	29	34	29	34	29	80
"	Twrch		19	-	-	-	-	-	-	-	-	-
"	Upper Clwyd		-	10	10	-	-	-	-	-	-	-
Lancashire	Stock Beck		4	4	4	4	4	4	4	4	4	-
"	Stankhill Beck		7	6	6	-	7	5	7	5	5	-
"	Hellifield		89	89	89	89	-	-	-	-	89	89
"	Upper Hodder		53	-	-	-	-	-	-	-	-	-
"	Roeburn		13	-	-	-	-	-	-	-	-	-
"	Dee (Lune)		46	-	-	-	-	-	-	-	-	-
"	Mint		-	17	-	-	-	-	-	-	-	-
"	Birk Beck		-	9	-	-	-	-	-	-	-	-
"	Flake Bridge		-	28	-	-	-	-	-	-	-	-
"	Lune tidal barrier		45	55	34	45	-	-	-	-	-	54
"	Killington		-	-	75	89	-	-	-	-	-	100
"	Borrowbeck		-	-	-	-	-	-	-	-	-	80
Cumberland	Wastwater[4]		6	-	-	-	-	-	-	-	-	-
"	Cocker		34	-	-	-	-	-	-	-	-	-
"	Marron		-	40	40	40	15	15	40	40	40	-
"	Irthing		73	-	-	-	-	-	-	-	-	73
Estuary Storage	Dee		-	-	-	-	200	-	200	-	260	-
"	Morecambe		-	-	-	-	250	450	250	450	-	-
"	Solway		-	-	-	-	170	170	-	-	-	-
Number of new inland reservoirs		41	17	15	13	9	7	7	7	8	11	8
Land used	Area in 000s of acres	22.5	14.5	14.0	13.5	12.5	3.5	3.5	5.0	6.0	10.5	11.6
	Approx. % saving on Prog. No. 1	-	35%	38%	40%	45%	85%	85%	78%	74%	53%	48%
Estimated Programme Costs	Total Outlay £M	426	342	372	381	380	402	421	387	409	376	397
	1970 Value £M	159	121	132	137	136	145	146	141	143	132	135
	Approx. increase in 1970 Value over minimum (Prog. No. 2)	31%	-	9%	13%	12%	20%	21%	17%	18%	9%	12%

1. *See chapter 6 following.*
2. *Including conversion of part of Thirlmere storage.*
3. *Enlargement of existing reservoir.*
4. *Controlled lake.*

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TABLE H

BASIC PROGRAMMES OF DEVELOPMENT PROVIDING (3820 Ml/d) at 2001

SCHEDULE OF SOURCES

METRIC EQUIVALENTS nearest 5 000 m³/d

1	2	3	4	5	6	7	8	9	10	11	12	13
River Authority	Reservoir or Site	SOURCES DEVELOPED AND REQUIRED YIELD IN EACH PROGRAMME (m^3/d)										
		Programme No.										
		1	2	3	4	5	6	7	8	9	10	5A[1]
Various	Changes of use of existing sources	Total of 41 Inland Reservoirs	290	290	290	290	290	290	290	290	290	390[2]
Northumbrian	Otterstone		-	740	740	950	180	180	840	425	335	955
"	Witton-le-Wear		415	415	415	405	-	-	-	415	415	-
"	Middleton		360	365	365	365	-	-	-	-	365	-
Yorkshire Ouse & Hull	Grimwith[3]		95	-	-	-	-	-	-	-	-	95
" "	Farndale		-	215	215	215	215	215	215	215	215	215
" "	Arkle Beck		200	-	-	-	-	-	-	-	-	-
" "	Bishopdale		205	-	-	-	-	-	-	-	-	-
" "	Birkby Nab		-	135	135	-	-	-	-	-	135	-
" "	New Couthwaite[3]		110	110	110	-	55	40	55	40	110	-
Dee & Clwyd	Clwyd Tube Wells		15	15	15	15	15	15	15	15	15	-
"	Brenig		365	365	365	365	130	155	130	155	130	365
"	Twrch		85	-	-	-	-	-	-	-	-	-
"	Upper Clwyd		-	45	45	-	-	-	-	-	-	-
Lancashire	Stock Beck		20	20	20	20	20	20	20	20	20	-
"	Stankhill Beck		30	25	25	-	30	20	30	20	20	-
"	Hellifield		405	405	405	405	-	-	-	-	405	405
"	Upper Hodder		240	-	-	-	-	-	-	-	-	-
"	Roeburn		60	-	-	-	-	-	-	-	-	-
"	Dee (Lune)		210	-	-	-	-	-	-	-	-	-
"	Mint		-	80	-	-	-	-	-	-	-	-
"	Birk Beck		-	40	-	-	-	-	-	-	-	-
"	Flake Bridge		-	125	-	-	-	-	-	-	-	-
"	Lune tidal barrier		205	250	155	205	-	-	-	-	-	245
"	Killington		-	-	340	405	-	-	-	-	-	455
"	Borrowbeck		-	-	-	-	-	-	-	-	-	365
Cumberland	Wastwater[4]		25	-	-	-	-	-	-	-	-	-
"	Cocker		155	-	-	-	-	-	-	-	-	-
"	Marron		-	180	180	180	70	70	180	180	180	-
"	Irthing		330	-	-	-	-	-	-	-	-	330
Estuary Storage	Dee		-	-	-	-	910	-	910	-	1185	-
"	Morecambe		-	-	-	-	1135	2 045	1135	2045	-	-
"	Solway		-	-	-	-	770	770	-	-	-	-
Number of new inland reservoirs		41	17	15	13	9	7	7	7	8	11	8
Land used	Area in km^2	91.1	58.7	56.7	54.6	50.6	14.2	14.2	20.3	24.3	42.5	46.9
	Approx. % saving on Prog. No. 1	-	35%	38%	40%	45%	85%	85%	78%	74%	53%	48%
Estimated Programme Costs	Total Outlay £M	426	342	372	381	380	402	421	387	409	376	397
	1970 Value £M	159	121	132	137	136	145	146	141	143	132	135
	Approx. increase in 1970 Value over minimum (Prog. No. 2)	31%	-	9%	13%	12%	20%	21%	17%	18%	9%	12%

1. *See chapter 6 following.*
2. *Including conversion of part of Thirlmere Storage.*
3. *Enlargement of existing reservoir*
4. *Controlled lake.*

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TABLE J

INLAND RESERVOIR DEVELOPMENT

Prog. No.	Description	by 1975		1976-1981		1982-1991		1992-2001		Total to 2001	
		No.	Acres (km^2)	No.	Land area Acres (km^2)	No.	Land area Acres (km^2)	No.	Land area Acres (km^2)	No.	Land area Acres (km^2)
	DIRECT SUPPLY SYSTEMS:-										
1	Free selection of inland reservoirs	10	5,000 (20.2)	11	6,000 (24.3)	12	6,500 (26.3)	8	5,000 (20.2)	41	22,500 (91.0)
	RIVER REGULATION SYSTEMS:-										
2	Free selection of inland reservoirs	2	300 (1.2)	8	6,000 (24.3)	3	5,100 (20.6)	4	3,100 (12.5)	17[1]	14,500 (58.6)
3	Selected inland reservoirs outside National Parks	2	1,250 (5.1)	6	6,500 (26.3)	3	4,100[2] (16.6)	4	2,150 (8.7)	15	14,000 (56.7)
4	Direct supply to Manchester from Killington	2	1,250 (5.1)	6	5,100 (20.6)	3	5,800[2] (23.5)	2	1,350 (5.5)	13	13,500 (54.7)
5	Eight large inland reservoirs mainly outside National Parks	2	1,250 (5.1)	4	6,150[3] (24.9)	1	2,400[2] (9.7)	2	2,700 (10.9)	9[3]	12,500 (50.6)
5A[4]	SEVEN LARGE INLAND RESERVOIRS MAINLY OUTSIDE NATIONAL PARKS	2	1,650[1] (6.6)	3	6,000 (24.3)	-	- -	3	3,950 (16.0)	8[1]	11,600 (46.9)
	ESTUARIAL STORAGE:-										
6	Morecambe, Dee and Solway Estuaries post-1981	2	950 (3.9)	5	2,550 (10.3)	-	-	-	- -	7	3,500 (14.2)
7	Morecambe and Solway Estuaries post-1981	2	950 (3.9)	5	2,550 (10.3)	-	-	-	- -	7	3,500 (14.2)
8	Morecambe and Dee Estuaries post-1981	2	1,250 (5.1)	5	3,000 (12.1)	-	750[2] (3.1)	-	- -	8	5,000 (20.2)
9	Morecambe Estuary post-1981	2	1,250 (5.1)	5	3,250 (13.2)	1	1,500 (6.1)	-	- -	8	6,000 (24.3)
10	Dée Estuary post-1981	2	1,250 (5.1)	5	3,100 (12.5)	3	4,950 (20.0)	1	1,200 (4.9)	11	10,500 (42.5)

1. *Includes enlargement of Grimwith Reservoir*
2. *Includes a second stage in the development of Otterstone*
3. *Includes a small reservoir at Stock Beck*
4. *See Chapter 6 following*

CHAPTER 5

DEVELOPMENTS IN EACH RIVER AUTHORITY AREA

57. To safeguard supplies in the period before the long-term programmes take effect some developments will be required to meet the needs of the region during the 1970s. Some of the more urgent of these are listed in paragraph 180 of the Working Party's Report. The isolated sources to which we referred in our paragraph 20 offer scope for a variety of local solutions which would not predjudice long-term planning; and the river authorities and water undertakings concerned should now consider urgently which developments should be pursued.

58. This selection of isolated sources in conjunction with ground-water development, and a few major regulating reservoirs, described in later paragraphs, which would merit inclusion in any long-term programme, will suffice to safeguard supplies during the next decade. Decisions on the remaining elements of the strategy can be thus deferred for a few years.

59. We are convinced that a regional approach is essential in the north if flexibility in water resource development is to be secured and the best use made of potential sources. A number of major projects feature in many of the programmes and would form the basis of a large-source solution, minimising the amount of disturbance. These projects should have priority of investigation. We now examine them in the context of the particular areas with which they are principally concerned.

Northumbrian River Authority

60. The Northumbrian River Authority have urgent short term needs. We recommended in our interim report[1] that a pipeline linking the major rivers in Northumbria should be planned as soon as possible. A link between the rivers Tyne and Tees would provide a solution for the immediate future. This link could provide additional water within the river authority area before new storage works are constructed. The extra yield could be achieved only by the co-ordinated control of the reservoir systems on the three main rivers.

61. We concur in the Working Party's view that the River Authority should arrange for the Tyne-Tees link to be in operation not later than 1975, and we are pleased to note that consultants have been engaged by the River Authority to investigate the possibilities of the link.

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1. *Interim Report on Water Resources in the North: H.M.S.O. 1967 Paragraphs 51 and 64.*

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62. This project should be followed soon after by the development of a major new source to provide at least 50 m.g.d. (230 000 m^3/d). We have considered four sites for major regulating reservoirs in the area. They are at Otterstone, Irthing, Middleton-in-Teesdale and Witton-le-Wear.

63. A regulating reservoir on the north Tyne at Otterstone could provide a yield of about 200 m.g.d. (910 000 m^3/d) from the regulated Tyne. It could meet the demands in the area until after 2001 or alternatively could meet the needs of both Northumbria and Yorkshire for about twenty years. The Northumbrian River Authority are investigating the site, which is on the northern boundary of the Northumberland National Park and largely within the area of the Kielder Forest. Most of the valley outside the reservoir site would be afforested. The water surface area would be 2,389 acres (9.68 km^2). The site contains some 41 properties. Most of these are owned by the Forestry Commission and some are unoccupied. A reservoir here would cause a minimum of disturbance and could be attractive in appearance, offering opportunities for a tourist centre, perhaps in the form of a countryside park and with a variety of recreational facilities. Such a centre might have advantages in concentrating the influx of visitors in a controllable and comparatively small space.

64. A site on the River Irthing is also being investigated by the Northumbrian River Authority. The river forms part of the Cumberland River Authority system, but a reservoir at its headwaters on the western boundary of the Northumberland National Park could be used to divert water into the Northumbrian system and regulate the South Tyne to provide a yield of about 70 m.g.d. (320 000 m^3/d). The site is remote, and except for three isolated farms desolate, with a probable alternative future of afforestation. The area does not seem to be closely linked with the other features of the Northumberland National Park, so that a reservoir here might not be a major intrusion. A reservoir would not affect Irthing Gorge, which is an area of Special Scientific Interest, provided that adequate care is taken during construction; but the Woomarsh, which is of local botanical interest, would be submerged.

65. The remaining two sites at Middleton and Witton - providing regulated yields of 80 and 90 m.g.d. (365 000 m^3/d and 410 000 m^3/d) from the Tees and Wear respectively - are of a different character. They contain some of the better agricultural land in the area and substantial numbers of properties; and reservoir proposals would be much more controversial here than at the other two

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sites. However, the combined yield of the Irthing, Middleton and Witton sites is comparable with the total yield of the Otterstone site. If the Otterstone site were found to be physically unsuitable, these three sites would, together, provide an alternative, Irthing being developed first.

Yorkshire Ouse & Hull River Authority

66. There are not many potential reservoir sites in Yorkshire and very few of these would add appreciably to regional resources. Many of the valleys where reservoirs might otherwise be sited are unsuitable because of the difficulties associated with pervious limestone, and also because they are in the scenic areas which are particularly important in this part of the country. The few sites which are suitable, particularly in the Derwent catchment, are thus specially important.

67. The Farndale project will increase by regulation of the River Derwent the quantities of water which can be abstracted from it for the benefit of south Yorkshire, Hull and Humberside. According to preliminary estimates, the reservoir will maintain a yield of 22 m.g.d. (100 000 m^3/d) and the construction of a tidal sluice on the river would provide an additional yield of 25 m.g.d. (115 000 m^3/d). Detailed investigations by the Yorkshire Ouse & Hull River Authority now in hand indicate that these yields may have been under-estimated.

68. Grimwith reservoir is to be rebuilt, and its new capacity should be considered in the context of regional demands. The Working Party indicate that the economic limits of storage here would provide a yield of 21 m.g.d. (95 000 m^3/d). Since Bradford urgently needs additional supplies, an early decision by the River Authority is required to proceed on these lines.

69. We have inspected the three most likely sites referred to by the Working Party, at Bishopdale, Arkle Beck and Birkby Nab, which would yield approximately 69, 44 and 30 m.g.d. (315 000, 200 000 and 135 000 m^3/d) respectively. All three have disadvantages. The geology of Bishopdale would make a reservoir expensive, and it is in an unspoilt part of the Yorkshire Dales National Park. Access to it is through Wharfedale, and if it were developed as a reservoir, it would inevitably attract many visitors who would pass through Wharfedale. A major reservoir at Arkle Beck would displace a large village community. A reservoir at Birkby Nab would submerge good agricultural land for a comparatively small development. If any of the three sites is to be investigated, it should be Bishopdale, perhaps at a later stage; but investigation here would probably be expensive.

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70. It may be that the greater part of the needs of Yorkshire after 1981 can best be met by large transfers from other river authorities' areas.

Lancashire, Mersey & Weaver, and Dee & Clwyd River Authorities

71. We consider together, for convenience, the related problems of the Lancashire, Mersey and Weaver, and Dee and Clwyd River Authorities. The Mersey and Weaver River Authority have no resources of strategic importance and they have in mind that short-term supplies for south Lancashire might be provided by a number of minor sources and the better use of existing sources locally. The adoption of such local expedients would be a departure from the established pattern of development in the area, but we are satisfied that this is justified in order to give time to reach the right long-term decisions. All major increments of supply to this river authority area after 1981 must, however, be based on imports from other areas.

72. Any consideration of the long-term needs of the region must of course include the possibility of modifying, for the benefit of the region generally, the arrangements linking Manchester supplies with those of other undertakings; not only the physical but also the financial and administrative relationships involved here will need to be examined in detail.

73. In considering the needs of Merseyside, in particular Liverpool and the North Wirral industrial area, we accept the Working Party's conclusion that the needs of Flintshire, Cheshire and Merseyside, at least until 1981, could be met most economically by a new reservoir on the River Brenig in the Dee catchment to regulate the Dee. Further development after 1981 will be influenced by decisions on the Dee Estuary. We have inspected the Brenig site, which is in a fairly remote upland valley, consists of relatively poor agricultural land and is unoccupied; we consider that if it is found physically suitable it should be developed. The land required for the reservoir is already owned by the Wirral Water Board.

74. Each of the two parts of the Lancashire River Authority's area which fall into the Preston and Fylde demand districts is expected to need a further 15 m.g.d. (68 000 m^3/d) by 1981. We concur in the Working Party's conclusion that these needs can be met by the development of ground water resources and modified use of existing storage in conjunction with abstractions from the Ribble, Wyre and Lune. After 1981 these districts, like those further south, will depend on major new sources in Lancashire or elsewhere.

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75. In order to produce major new supplies from the Lancashire rivers the Working Party suggest that storage might be developed at Hellifield to regulate the River Ribble, and at Killington, Borrowbeck, or Haweswater to regulate the River Lune. These developments would give yields of 89, 132, 80 and 150 m.g.d. (405 000, 600 000, 365 000 and 680 000 m^3/d) respectively which could be increased if it is found possible to construct a tidal barrier on the River Lune. The use of Haweswater would involve enlarging the existing reservoir and diverting the water into the Lune catchment. But any solution of the problem of industrial Lancashire based on these developments would prejudice decisions on estuary storage; and we would prefer not to reach final conclusions on any of them until the estuary studies are complete. If early inland development is necessary Hellifield offers most advantages. It is a key source which appears in all the Working Party's programmes which do not include Morecambe Bay storage, and if Morecambe Bay is used for storage a reservoir at Hellifield could be used as a staging post in moving water from the Bay to the Yorkshire rivers.

76. The Hellifield site offers great potential for the development of recreational facilities; it could attract people from industrial Lancashire and Yorkshire and thus relieve some of the existing demand on the Lake District. It was considered acceptable by the Jellicoe Committee[1] despite its great impact on agricultural land. In our view also this disadvantage is substantially outweighed by the other benefits.

77. The Killington site has large storage potential which could be developed in a variety of ways; these would all require extensive embankment works whose cost could be established only after detailed site investigation. The site has little natural catchment, but it is one of two inland sites into which water could conveniently be pumped from the rivers draining into Morecambe Bay and in this sense offers an alternative to storage in the Bay. The other inland site, in the Winster Valley, would be much more controversial and probably more expensive in use.

78. The Borrowbeck site is well located on a tributary of the River Lune. A reservoir here could conveniently be used to regulate the Lune and could receive water pumped back from the river during periods of high flow. A proposal for a reservoir at Borrowbeck was considered by the Jellicoe Committee to be acceptable on amenity grounds. The construction of the motorway close to the site may well give additional weight to the Committee's view. However a special geological investigation would be needed of the possible effects on

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1. *Conference on Water Resources in the North-West: H.M.S.O. 1963.*

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the reservoir sides of rapid 'draw down', i.e. reduction in water level. The site would be an alternative development to Hellifield if an inland source becomes necessary before the long-term decisions are taken.

79. The existing Haweswater reservoir in the area of the Cumberland River Authority is the largest in the country, with a storage of about 18,000 m.g. (81 830 000 m^3). A new dam could probably be built immediately downstream of the existing one to raise the level of the water by 100' (30.5 m) or possibly 200' (61 m). This development would be costly, partly because the new reservoir would have to be filled by pumping water from the River Eden, and partly because, in order to use the water in Lancashire, it would have to be delivered by tunnel to the headwaters of the Lune. The site is in the Lake District National Park, but the valley has been used for water storage for many years and an extension of that use might prove acceptable.

80. The Working Party list a number of other sites in the area of the Lancashire River Authority. Some of these have considerable capacity; most of them are open to strong amenity or other objections and should be looked upon only as substitutes for the projects we have named in this area, which we consider to be those most suitable for investigation.

Cumberland River Authority

81. The problems of the Cumberland area are concentrated along the west coast in the areas of supply of the South and West Cumberland Water Boards. Carlisle should be adequately supplied for very many years by the resources of the Eden catchment, and the rest of the River Authority's area should be self-sufficient from local sources. In West Cumberland there are three major considerations. These are first, the need to provide for the demand arising from the normal growth of population and the development of existing industry, which existing sources should be able to meet until 1981; second, the policy of attracting new industry to the area, for which the availability of ample water supplies is considered to be very important; and third, the maintenance, in dry periods, of adequate flows in the River Derwent, which are at present likely to be unsatisfactory because of the authorised abstractions which could occur above the tidal limit.

82. After allowing for the development of isolated sources the Working Party estimate that the final net deficiencies in west Cumberland (including that part of the South Cumberland Water Board which lies within the Lancashire

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River Authority area) would amount to 15 m.g.d. (70 000 m^3/d) in 1981 and 40 m.g.d. (180 000 m^3/d) in 2001.

83. To provide for local needs in the near future advantage should be taken of the development authorised at Ennerdale and of any ground water which can be obtained in west Cumberland. We agree with the River Authority that these must be followed by a measure of regulation of the outflow from Bassenthwaite Lake until further resources are developed. We believe that a worthwhile additional supply can be developed in this way without adversely affecting the appearance of the Lake. During the period covered by these interim measures the probable scale of future demand for water by incoming industry may be more clearly seen.

84. For the longer term there are two possibilities. The River Authority have proposed a reservoir at Marron to provide a yield of about 60 m.g.d. (270 000 m^3/d), which could be increased by a tidal weir control to about 100 m.g.d. (455 000 m^3/d). This yield would meet demands until well beyond the turn of the century, as well as providing increases in river flows. But the large capital cost would make the water expensive in the earlier years and would inevitably affect the costs of all abstractors in the area of the Authority. The scheme could not contribute to supplies outside Cumberland. Nevertheless the site investigations already started should be completed.

85. We prefer an alternative solution which is linked with regional development and flexible in operation. This consists of using water from Thirlmere to regulate the flow through Bassenthwaite Lake. The unnatural fluctuations in the level of the lake caused by the interim control scheme mentioned above would thus be eliminated, though some measure of control at the Lake outlet would be permanently required in order to avoid excessively high levels caused by discharges from Thirlmere. We consider that this solution merits the detailed investigation necessary to establish its feasibility. Any necessary works in Bassenthwaite Lake could be unobtrusive, and by ensuring the stability of the lake level would enhance rather than threaten its amenities. The use of Thirlmere water for Cumberland would depend upon first securing an alternative source of supply for Manchester.

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CHAPTER 6

A PROGRAMME OF INVESTIGATION

86. Development of water resources in the future must make allowance for the following essential characteristics of the region:

(i) Demands over the whole region can be met by an integrated regional pattern of development with major sources interlinked and programmed to meet needs when and where they arise. The only exceptions are small local demands and those in the industrial strip on the west Cumberland coast.

(ii) There are three large estuaries in the region which might be used for storage. Two are being investigated, and important decisions will have to be taken in 1972 on the relative importance of estuary and other forms of storage.

(iii) Storage sites are scarce in the area of the Yorkshire Ouse and Hull River Authority, where demand is high and may be increased by developments on Humberside.

(iv) Water is at present transferred across the areas of the Cumberland, Lancashire and Mersey and Weaver River Authorities to serve south Lancashire.

87. We consider that in the area of the Northumbrian River Authority the best way of meeting future demands will be to construct one or more major inland reservoirs. A reservoir at Otterstone, with an aqueduct linking the Tyne and the Tees, offers the most flexible arrangement. However if investigation shows Otterstone to be physically unsuitable, the alternative of Irthing, together with Middleton and Witton-le-Wear, must be considered. The Irthing site is being investigated in parallel with Otterstone, and could well provide a supply for a sufficient time ahead to cover the period of investigation for Middleton and Witton.

88. West of the Pennines, there will be a choice in 1972 between two patterns of development, when the relative merits of estuary and inland storage can be more precisely compared. The sites for the major projects essential to an inland reservoir system must therefore be fully investigated by that date. Water may have to be transferred across the Pennines into the river system of Yorkshire to supplement supplies there. Thus a complex transmission arrangement could

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develop involving moving water between the areas of four river authorities, and possibly five, if the Dee Estuary is used to provide water northwards.

89. Among the inland source programmes put forward by the Working Party, given the dependence of Northumbria on a major inland resource and the need to compare a limited number of inland resources on the west of the Pennines with the estuary storage projects, we prefer one on the lines of Programme No. 5. Such a programme would, at some additional expense, limit the amount of disturbance caused by reservoir projects and incidentally limit the number of sites to be investigated in a short period of time. If any of them are found to be unsatisfactory, the alternatives will, of course, have to be investigated, and a greater number of smaller sites may be needed.

90. In view of the problems associated with reservoirs in the limestone areas of the Yorkshire Ouse and Hull River Authority in the Yorkshire Dales National Park, we have sought to devise a programme which does not depend upon Bishopdale and other large reservoirs in that area. We regard Middleton and Witton only as a possible alternative to the major development at Otterstone; and we do not regard a reservoir at Marron as a major source capable of development for the regional system. We put forward, therefore, Programme No. 5A.

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Programme No. 5A

7 large inland sources

(1970 value £134 million)

	Yield	
	m.g.d.	Thousands of cubic metres per day
New Reservoirs		
Farndale	47	215
Brenig	80	365
Otterstone	210	955
Hellifield	89	405
Borrowbeck	80	365
Irthing	73	330
Killington	100	455
Other sources		
Enlargement of Grimwith Reservoir	21	95
Change of use of various existing sources	64	290
Conversion of part of Thirlmere storage with a tidal barrier on the Derwent in Cumberland	40	180
Lune tidal barrier	54	245
	858	3 900
Deduct for making good to Manchester the loss of supplies from part of Thirlmere storage	18	80
Total additional yield at 2001	840	3 820

As an alternative to Borrowbeck and Killington, Haweswater should be considered as a source for enlargement to yield a further 180 to 270 m.g.d. (818 000 to 1 230 000 m^3/d).

91. Programme No. 5A costs £14 million more at 1970 values than the cheapest programme (No. 2); but £1 million less than the original Programme No. 5. Programme No. 5A (illustrated in figures a, b and c) includes no reservoir sites, other than Farndale, involving more than the fringes of National Park areas, and only two (Farndale and Hellifield) of agricultural importance.

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92. We consider that the seven major sites included in this programme, with an enlarged Haweswater as the alternative to Borrowbeck and Killington, should be regarded as the inland sources forming the long-term alternative to estuary storage. The proposed reservoirs at Brenig, and at Otterstone or Irthing, will be required whatever is decided about estuary storage, and these sites should be investigated first. Full site investigations and cost estimates for Hellifield, Borrowbeck, Killington and Haweswater will be required by 1972 for comparison with the estuary storage projects; and these investigations also should begin now.

93. At the same time, the problems of water transmission inherent in any regional programme of development should be investigated. Five transmission links may be required: from the Tyne to the Tees; from north Lancashire to south east Lancashire and Merseyside; from the Dee to Merseyside and south east Lancashire; from Morecambe via Hellifield to Yorkshire; and from Northumbria to Yorkshire. Of these, the Tyne-Tees link is already under investigation, and the other four should be investigated by 1972.

94. This report has been produced in advance of the river authorities' statutory surveys under Section 14 of the Water Resources Act 1963. However, these surveys are now approaching completion; and in due course they will provide further information to be considered, in the context of this report, with the results of investigations indicated above and of the Morecambe and Dee Estuary studies.

95. We have referred elsewhere to the need for flexibility in planning for the long term. This means not only that short-term projects must not prejudice the major decisions which will be required later, but also that the process of planning must itself be able to take account of new information and new situations as they arise. It is thus most important that all those concerned with the planning of water resources development should systematically review their plans at regular intervals.

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CHAPTER 7

SUMMARY OF PROJECTS

96. We summarise below the projects which we recommend in this Report. They are in four groups: (a) projects to be completed as soon as possible to meet urgent needs; (b) projects which will be needed in the long term whether or not estuary storage is adopted, and which should therefore be investigated forthwith; (c) projects which require investigation so that they can be compared with estuary storage proposals; and (d) projects which may need investigation as alternatives to (b) and (c) if problems are encountered.

Project (Numbers in brackets refer to paragraphs in the Report)	River Authority Area
(a) Projects to be completed as soon as possible	
1. Farndale Reservoir and Derwent tidal sluice (67)	Yorkshire Ouse and Hull
2. Grimwith Reservoir (68)	" " " "
3. Tyne-Tees Link (60-61)	Northumbrian
4. Local Schemes (71)	Mersey and Weaver
(83)	Cumberland
(74)	Lancashire
(b) Projects for immediate investigation	
5. Brenig Reservoir (73)	Dee and Clwyd
6. Otterstone and Irthing Reservoirs (63-64)	Northumbrian
7. Thirlmere/Bassenthwaite Control Works and Workington tidal sluice (84-85)	Cumberland

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	Project	River Authority Area
(c)	Projects for investigation by 1972 for consideration with estuary storage	
8.	Hellifield Reservoir (75-76)	Lancashire
9.	Killington Reservoir (77)	"
10.	Borrowbeck Reservoir (78)	"
11.	Haweswater enlargement (79)	Cumberland
12.	River Lune tidal sluice (75)	Lancashire
	Transmission links (93)	
13.	Morecambe-Hellifield-Yorkshire	Lancashire Yorkshire Ouse and Hull
14.	Northumbrian-Yorkshire	Northumbrian Yorkshire Ouse and Hull
15.	North Lancashire-South East Lancashire and Merseyside	Lancashire Mersey and Weaver
16.	Dee-Merseyside and South East Lancashire	Dee and Clwyd Mersey and Weaver
(d)	Projects for possible investigation as alternatives to (b) and (c)	
17.	Witton-le-Wear Reservoir (63)	Northumbrian
18.	Middleton Reservoir (63)	Northumbrian
19.	Marron Reservoir (82)	Cumberland

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REPORT ON WATER RESOURCES IN THE NORTH

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Map: General Map of the Study Area showing Location of Major Resources and Transmission Links (contained in attached wallet)

Figures: Illustrating a possible programme of development

a (i)-(iii): Strategy for development in 1981, 1992 and 2001

b : Demand/Resource development graph

c : Incidence of expenditure

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